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# ORGANIZATION FACTORS IN THE QUALITY AND RELIABILITY OF MARINE SYSTEMS

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## ABSTRACT

Organization factors play critical roles in determining the quality and reliability of marine systems such as offshore platforms, ships, and pipelines. These organization factors have dramatic influences on the quality and reliability achieved during design, construction, and operation of marine systems. This paper focuses on enhancing reliability through reducing failure during the operational phase of marine systems. It discusses the importance of a model of risk mitigation within organizations in which error can result in catastrophic outcomes, and illustrates the failure of these factors to operate appropriately in the Exxon Valdez accident. It then examines linkages among organizations that must be thought about in managing risk.

## RISK MITIGATION WITHIN ORGANIZATIONS

Most of the research on risk and risk avoidance in organizations addresses only engineering issues (e.g., structural design and integrity) which is itself a significant limitation. The existing behavioral literature is limited in part because it confines itself to various specific contexts of risk. The "disaster" literature looks exclusively at catastrophic *failure* in high risk environments (e.g., Shrivastava, 1987; Perrow, 1984). At the opposite end of the spectrum are behavioral researchers who look at *non-failure* of possibly catastrophic magnitude in "High Reliability Organizations" or HROs (i.e., Roberts & Rousseau, 1989; Roberts, 1992; Weick & Roberts, 1993). These are organizations which have a high potential for failure but where failure occurs much less often than is predicted or expected.

The writers in each arena fail to test their theories and conclusions about the causes of failure/non-failure in each others contexts. For example, Perrow's, conclusions about the inevitability of accidents are undermined by the existence of organizations that "should" fail according to his model, but which have not yet failed. Similarly, we do not know if the explanations Roberts gives for non-failure or accident avoidance in HROs (1992) also hold in failing organizations.

Based on her examination of the conceptual underpinnings of both the disaster and HRO literatures and case studies of a number of well documented organizational catastrophes, including the grounding of the Exxon Valdez, Libuser (1994) developed and tested a model of risk mitigation. This model has five factors:

**1. Process Auditing:** An established system for ongoing checks designed to spot expected as well as unexpected safety problems. Safety drills are included in this category as well as equipment testing. Follow ups on problems revealed in prior audits are a critical part of the function.

**2. Reward System:** The reward system is the payoff that an individual or an organization gets for behaving in one way or another. In this case, we are concerned with reducing risky behavior. An organization's reward system has a powerful influence on the behavior of individuals in it. Similarly, interorganizational reward systems influence the behavior of organizations.

**3. Degradation of Quality and/or Inferior Quality:** This refers to the essential quality of the system involved as compared to a referent system that is generally regarded as the standard for quality. This allows information difficulties to surface.

**4. Perception of Risk:** Two elements of risk perception are involved here. (1) Whether or not there is any knowledge that risk exists at all, and (2) If there is knowledge that risk exists, the extent to which it is acknowledged appropriately or minimized.

**5. Command and Control:** This factor is borrowed from Roberts (1988, 1989, 1992). Roberts outlined command and control elements as separate factors, but they are combined here with the separate factors listed as subfactors and with rewards and punishment removed to occupy its own factor. The command and control elements are:

a. *Command by negation* which includes migration of decision making (the person with the most expertise makes the decision).

b. *Redundancy* (people and/or hardware), i.e. backup systems exist.

c. *Formal rules and procedures*, a definite existence of hierarchy but not necessarily bureaucracy in the negative sense.

d. *Training*, imparting both skills in task performance and knowledge of why the tasks are performed.

e. *Senior managers who can see the "big picture"*, i.e. they don't micromanage or encourage traditional power strategies, and they empower the employees, rewarding production and promoting development of capabilities.

Libuser finds that organizations which fail to address these five factors are more likely to experience failure than are organizations which attend them carefully. We use the Exxon Valdez accident to exemplify the outcome for a "mega" organization which failed to take these factors into account (Moore, Bea, Roberts, 1993).

First, with regard to process auditing the Coast Guard renewed Captain Hazelwood's master's certification without checking his driver's license record (which would have shown three suspensions for driving-while-intoxicated). Furthermore, the state of Alaska, through its inadequately funded Department of Environmental Conservation (DEC), was completely unable to monitor the oil company supported watchdog organization, Alyeska, and make it conform to its contingency plan. Alyeska acted with impunity.

Second, the reward system was based on cost minimization. The Coast Guard, as an organization, tried to minimize radar costs, so it downgraded its systems and also stopped plotting tanker crews. Alyeska, as an organization, also tried to minimize costs, so it failed to buy more modern or larger equipment, or even properly maintain the equipment it had. Third with regard to degradation of quality the Alyeska consortium allowed its spill equipment to deteriorate and/or be stored improperly; it refused to upgrade the equipment over time.

Fourth, with regard to perception of risk, there is ample evidence that the Coast Guard, in general, regarded the risk of an accident as minimal since it downgraded its radar system and stopped tracking ships as far as it had previously done. Furthermore, Alyeska regarded spill risks as minimal; only under protest did it provide a contingency plan to the Alaska DEC for a 200,000 barrel spill.

Finally, with regard to command and control the command and control system was dysfunctional in many ways at Valdez. There was no adequate command by negation aboard the Exxon Valdez or at any of the other organizations involved. There was no redundancy, particularly of ship tracking and none on the ship's bridge which might have detected error before it was too late. Alyeska, for one, refused to abide by the rules and procedures that it had agreed upon with the Alaska DEC. There is no evidence of adequate training in any of the organizations involved and apparently no one had "the big picture.

## SYSTEM RELIABILITY FOR RISK MITIGATION

While it is important to focus on risk mitigation within organizations it is also important to think about how organizations are hooked together as systems of organizations, as is amply illustrated in the Exxon example.

There is no organizational literature on system reliability (Roberts, 1994). We have developed neither a language nor a set of constructs that can help managers of various parts of systems operate their part of the system to insure maximum reliability and safety. At the moment all we can do is point to examples of operational systems and provide tentative suggestions about the issues that need concern researchers and operators.

The U. S. marine transportation system is as good an example of a system as any. It is a complicated large scale system with a variety of elements that influence one another: vessel owners and operators, port authorities, maritime unions and labor organizations, maritime insurance companies, and domestic (U.S. Coast Guard) and international (International Maritime Organization) regulatory bodies. Performance of this system affects many nation's economies, the safety of ships and their crews, the well-being of inhabitants near ports and waterways, and the natural environment.

Over the past decade, the safety, effectiveness, and efficiency of the system have become major concerns, primarily because of a continuing string of major shipping disasters: *the Admiral Nakhimov*, in August 1986; the *Herald of Free Enterprise*, in March 1987; the *Dona Paz*, in December 1987; the *Exxon Valdez*, in March 1989; and the *Braer*, in January 1993 (Marine Transportation Research Board, 1976; National Transportation Safety Board, 1990; National Research Council, 1990; 1993). Each of these maritime accidents involved considerable loss of human life and/or catastrophic ecological damage. These tragedies, as well as many other reported marine casualties of a less serious nature, are "perhaps but the tip of the iceberg, i.e., the visible portion of a very much larger number of mishaps and generally unsafe practices" (Bryant, 1991).

Acceptable levels of risk for the marine transportation system have not been generally defined and accepted, but recent past experience with pollution incidents shows that current risk levels in the system are unacceptable (National Research Council, 1993). Reduction of operational risk in ports, waterways, rivers, and coastal waters will depend heavily on measures to improve all parts of the marine transportation system: its human elements, technology, organizational structures, and organizational cultures. Improvements in organizational structure and processes for interdependent decision making and official oversight, as well as in technologies, have recently been identified as important changes needed throughout the marine transportation system (National Research Council, 1992; 1993).

Management of U. S. ports and waterways is loosely integrated, with substantial opportunity for problems and errors to occur (Perrow, 1984). No one has comprehensive responsibility to assure that each of the system elements works efficiently and effectively (National Research Council, 1990).

Because there is substantial variation in the nature of risk and exposure in different ports, and the safety data have not been normalized among ports, casualty rates by themselves do not necessarily reveal whether or not any one port is any more or less safe than any other (Abkowitz, Bower, Dailey, and Golarruga, 1985; Maio, et al., 1991). Local tolerances for operational risk vary among ports and waterways, and are often influenced by tradeoffs between safety and economic efficiency (Wenk, 1986; National Research Council, 1983; 1992;).

Many reports that assess safety and risk in the industry examine task performance problems and situation factors in great detail (e.g., Cahill, 1983; 1985; Gates, 1989), rather than systemic problems. Thus, there is, in fact, a great need in the marine transportation system for improved performance monitoring, vessel safety control, and management of waterway systems, as well as improved coordination and cooperation between state and federal regulators, maritime interests, and the affected public (National Research Council, 1993).

## CHARACTERISTICS OF THE SYSTEM

From a safety perspective, a number of important features emerge concerning the U. S. Marine transportation system (following Reason, 1991; p. 1):

• *It is a complex, well-defended system.* It possesses a large number of organizational safety devices. Senior operators are, for the most part, rigorously selected, highly trained, and closely regulated,

• *It is a high-hazard, low-risk system.* It operates in an intrinsically dangerous environment, yet the probability of an accident occurring remains low.

• *Though they occur infrequently, the system is subject to unacceptably catastrophic accidents involving large numbers of fatalities, huge financial losses, and/or ecological disaster,*

• Subsequent investigations reveal that *accidents frequently arise from the adverse conjunction of several root causes,* each necessary, but none sufficient to cause the accident,

• *Human failures increasingly outweigh technical failures in their contribution to serious accidents*, and

• *There is a moderate to large distance, both geographical and professional, between operators and top management.*

## NEEDS TO UNDERSTAND ORGANIZATION SYSTEMS

While considerable research and development is in progress in large scale systems, the principal focus of this research is often on individual, team, or group performance, technology development and assessment, and on organizational structures taken one at a time. While these are important considerations, they are insufficient bases for assessments of the safety propensity of large scale systems. Instead, careful assessments of the interactive effects of subsystems on each other; of the decision and organizational support required by large scale systems; of underlying causal factors, interactions, and preventive measures; and of the impact of anticipated and unanticipated events would provide more informed bases for problem solving and decision making in large scale systems.

To study error in large scale systems, a common conceptual scheme for organizing variables is required. A large number of research issues worthy of study can be identified. Researchers must come to grips with what issues, among the many of relevance, they should address. Here we identify four areas worthy of research attention.

*Organization structure.* Variations in organizational structure have been explained by differences in task uncertainty, the number of organizational units required for decision-making, and the interdependence of those units (Galbraith, 1973). Based on analyses of these factors, organizational structures have been recommended that permit decoupling. The focus is on decoupling tightly coupled, interdependent systems to allow local control and autonomy. We suggest that loosely coupled or entirely disconnected systems can cause accidents as readily as can tightly coupled systems. The challenge for large scale systems is to identify the degree of connectedness, coupling, and interdependence appropriate to the industry.

*Decision making.* Some considerable research exists on group and individual decision-making, but much of it was conducted in laboratories in which conditions seldom replicate field conditions. Research is non existent on decision-making in large scale systems. One challenge to large scale systems is to decide how much decision connectivity is required.

*Communication.* Communication theories have typically focused on message exchanges between parties, considering information content, channels, and the nature of message senders and receivers (Berlo, 1977; Bormann, 1980). Studies are needed that examine the nature of effective communication in error-free large scale systems: characteristics of parties communicating; the number, type and frequency of messages being communicated; the nature of channels used; differences between electronic and face-to-face communication; and the impact of different media on the safe and effective transmission of communicated ideas in large scale systems.

*Culture.* Organizational culture studies should not only focus on one organization (i.e, a shipping company) but on networks of organizations (e.g. shipping companies *and* vessel traffic services, and local pilot associations). A myriad of issues suggest themselves. Recently, some research attention has been devoted to understanding how organizations learn (Attwell, 1992; March, Sproul, and Tamuz, 1991; Schein, 1992). How organizations learn certainly influences how they approach multi participant decision making tasks; which is part of their culture and another important research issue in the design and operation of large scale error-free systems. The fabrics of the marine industry's various cultures are varied, and little understood. A challenge to error-free large scale systems is to decide which of its aspects needs to concern itself with developing reliable and safe cultures.

## CONCLUSIONS

This paper highlights organizational factors important in developing reliable and high quality marine systems. A model of risk mitigation is presented and evidence provided that when factors of the model are not given appropriate attention catastrophic results can occur.

The application of the model to various players (one at a time) in the Exxon Valdez accident began to show the importance of focusing not on single organizations but on interdependent systems of organizations. The U.S. Marine Transportation system is a good example. Some problems with our knowledge base of the system are discussed followed by a description of characteristics of the system that are important to its safety. Finally, specific research to better understand marine systems is suggested.

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